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Technical Series

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## DETERIORATION OF PARKING STRUCTURES: EXTENT, CAUSES AND REPAIR CONSIDERATIONS

### Introduction

Parking structures are subjected to demanding service conditions. These include live load effects, such as vehicular impact and abrasion, as well as environmental effects such as high humidity and moisture levels, thermal variations, and attack from de-icing salts. Together these factors can lead to premature deterioration of parking structures even when constructed to meet appropriate building codes. Major parking structure deterioration first became apparent in the late 1970's and the problem became widespread within about a decade. This work was commissioned by CMHC to identify factors that favourably affect the serviceability of parking structures.

### Research Program

This work presents an overview of the most important aspects of corrosion-induced parking structure deterioration resulting from repeated exposure to roadway de-icing salts and moisture. It represents the third study carried out by CMHC concerning parking structure deterioration. The first two were carried out by J.A. Bickley of Trow Ltd. and published in 1981 and 1984, respectively (see Highlight 00-128). This document references key points from the 1984 survey and provides additional material from the author's own experience to provide an overview of parking structure deterioration and repairs.

### Results

The information in this report relates to the evaluation and repair of heated, cast-in-place underground parking garages that typically have suspended slabs.

The report is written in six parts:

- 1.0 Introduction
- 2.0 Causes and Types of Deterioration
- 3.0 Evaluating the Extent of Deterioration
- 4.0 Repair Options and Techniques
- 5.0 Inspection/Maintenance Procedures
- 6.0 Economic Issues

It is intended as a reference for technical audiences not yet fully conversant with the deterioration problem. The key points outlined in each section are provided below.

### Causes and Types of Deterioration

The most important cause of deterioration to these structures is attributed to reinforcement corrosion promoted by road salts. In the presence of an electrical potential in the reinforcing steel, an electrolyte to conduct electrical current, and oxygen, the corrosion process will occur. The factors that influence the rate of corrosion include:





- Chloride concentration: higher levels cause higher rates of corrosion;
- Moisture content: corrosion normally stops early on in the initial drying process and should not start again unless the concrete becomes almost saturated;
- Concrete mix: reduced water cement ratios help limit the ingress of water, oxygen and chlorides;
- Concrete cover: increased cover significantly reduces the corrosion rate, primarily by reducing chloride ion penetration.

Other types of concrete deterioration include cracking, leaching and scaling.

### **Evaluating the Extent of Deterioration**

The objectives of an investigation program into parking structure deterioration are:

- To establish the nature and extent of deterioration;
- To determine the underlying causes of the deterioration; and
- To develop a comprehensive repair scheme.

The investigation procedure itself must be systematic and thorough. A two-phase approach is recommended.

The first phase is a preliminary visual survey to establish the nature of the problem, plan the detailed investigation and gain insight into the structural implications of the defects. Specifically, the preliminary survey would include: a document review; visual inspection and photographic record; sample removal of spalled concrete for preliminary examination of extent of reinforcement corrosion and possibly chloride ion content tests; and chain drag surveys and covermeter tests to determine the extent of delamination and concrete cover, respectively.

The second phase should quantitatively determine the following key items: extent of corrosion (half-cell measurements); extent of delamination; concrete cover; chloride levels; concrete permeability; and concrete strength. Other issues that may be considered include: concrete quality (compressive strength, cement content, density and air content); electrical resistance of waterproofing membranes to evaluate their permeability to water; and slab drainage paths to indicate areas susceptible to ponding. The data is typically presented visually on a plan of the garage.

### **Repair Options and Techniques**

The repair program must address structural and functional considerations. The final selection of a repair option will depend on the assessment of the garage condition and budget limitations, but could include the following repair options:

- Epoxy injection of cracks and installation of a waterproof membrane wearing course.
- Replacement of deteriorated concrete and reinforcements, and installation of a waterproof membrane and wearing course.
- Replacement of deteriorated concrete and reinforcement, and installation of a dense concrete overlay.
- Replacement of deteriorated concrete and reinforcement, and installation of a cathodic protection system.
- Complete demolition and rebuilding of the structure.

## **Inspection/Maintenance Procedures**

Due to their specialized functional requirements and the demanding environmental conditions under which they must perform, parking garages require periodic inspection and maintenance procedures that recognize their special status as structures. An annual visual inspection for damage or leaks is recommended. Regular maintenance should also be carried out, including cleaning of drains, flushing surfaces with water and maintaining adequate ventilation. Reducing or eliminating heating in the garage can also prolong the life of the floor.

## **Economic Issues**

Parking structure repair will generally involve a compromise between what is technically possible and what is economically feasible. Long term cost comparisons can be developed using a life cycle cost analysis technique. Generally, garage repairs carried out to high standards tend to be cheaper in the long run than the use of less desirable, but initially cheaper repair methods. It has also been found that funds spent on detection and repair early in the service life of the garage will keep the repair costs significantly lower than delaying repair measures until extensive damage has occurred.

## **Implications for the Housing Industry**

This report presents an overview of the most important aspects of corrosion-induced parking structure deterioration resulting from repeated exposure to roadway de-icing salts and moisture. An assessment of repair and maintenance options is provided for multi-storey cast-in-place reinforced concrete underground parking garages, which typically require comprehensive repair schemes to correct deficiencies. The document was originally intended as a reference for technical audiences not yet fully conversant with the deterioration problem. Today, it serves as a valuable resource, providing a concise summary of the issues surrounding parking garage deterioration and repair.



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### **Housing Research at CMHC**

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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